Decision-making through performance simulation and code compliance from the early, schematic phases of building design

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Abstract. This paper is about the merging of two software applications that allows building decision makers to consider code compliance and to use performance simulation tools from the early, schematic phases of building design. By making the capabilities of a code compliance tool available at the early schematic phases of building design, the hope and expectation is that users will use this software to address the mandatory code compliance issues and thus have an opportunity to address other performance issues as well.

Keywords. Decision-making, Energy, Codes, Simulation, EN832.

Introduction

Building performance simulation tools have been available for a long time, addressing various performance issues such as lighting, indoor air quality, comfort, energy, environmental impact, etc. However, most performance simulation tools have steep learning curves and are hard and time-consuming, thus expensive, to use (Hien, 2000). As a result, most design decisions are made intuitively, without actual performance prediction with respect to a variety of performance aspects, such as lighting, energy, comfort, etc., which require the use of performance simulation models.

While performance simulation is not required and/or performed but in high-visibility, large building projects, code compliance is required for all buildings. As building codes move from prescriptive to performance-based criteria, code compliance tools move towards incorporating performance simulation models. U.S. energy codes, for example, are based on the DOE-2 building energy performance simulation software (Birdsall, 1990; ASHRAE 90.1-1999). European energy codes are based on an energy balance computation model that takes into account the internal and external temperature variations and a utilization factor of the dynamic effect of internal and solar heat gains (EN 832; prEN ISO 13790).

Although the European EN 832 standard was primarily designed for use in judging compliance with regulations expressed in terms of energy targets, it was also intended for use in comparing the energy performance of various design alternatives for a planned building, or for assessing the effect of possible energy conservation measures on an existing building. However, code compliance tools (just like performance simulation tools) are mostly used at the end of the building design process, after most of the building design decisions have already been made. At that time, only minor design modifications are feasible.

This paper is about the merging of two software applications that allows building decision makers to consider code compliance and to use performance simulation tools from the early, schematic phases of building design. The two software applications are the Building Design Advisor (BDA) and ATON, which is a German acronym for “General Thermal and Ecological Compliance.” The BDA is a framework that acts as a data manager and process controller to allow concurrent use of

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multiple simulation tools and databases from the early schematic phases of building design. ATON is a code compliance tool that handles multiple thermal and hygrothermal prescriptive codes of Austrian counties.

By making the capabilities of ATON available at the early schematic phases of building design through BDA, the hope and expectation is that users will use the BDA software to address the mandatory code compliance issues and thus have an opportunity to address other performance issues as well, such as those related to lighting, day-lighting and energy performance. The BDA allows comparison of multiple design alternatives with respect to multiple performance criteria, thus giving an opportunity to decision-makers to consider designs that exceed code requirements. This is especially useful in performance-based contracts and utility programs, which reward designs whose performance exceed code requirements.

Background

ATON

ATON is an object-oriented structured building physics software, developed at the Department for Structural Analysis at the Graz University of Technology, and has been successfully used for teaching relational problems in building-physics (Reichard, 1999). It follows a "question & answer" concept, where every manipulation of data is immediately monitored in a graphical representation.

In its initial version, ATON was designed as a code compliance tool to handle multiple different thermal and hygrothermal prescriptive codes of Austrian counties. The original objective was to support students in learning the correlation between the thermal and hygrothermal performance of a multi-layer component under varying boundary conditions. One of the main benefits of ATON is that after the input of each layer the effect on the component construction is reflected immediately. In this way, ATON makes it easy for students to understand the thermal and moisture effects of different construction layers, such as a vapor-proof barrier, at different positions within a boundary construction.

The shifting from prescriptive- to performance-based codes, through the implementation of the EN 832 standard in Austrian codes (ÖNORM B 8110-1, 1998), introduced numerous additional standards that define calculation models and procedures for building components, e.g., windows, consideration of thermal bridges, ground heat transfer, etc. (EN ISO 6946; EN ISO 10077-1; EN ISO 10211-2; EN ISO 13370; EN ISO 13789). The relationships among multiple computational standards made it increasingly complicated to identify the appropriate standards for the required computations. ATON's main objective has been the streamlining of the code-compliance computational procedures.

BDA

The BDA (Building Design Advisor) software is a general software framework with data management and process control capabilities that allow concurrent, integrated use of multiple simulation tools and databases (Papamichael, 2000). The BDA software was developed by the Building Technologies Department of the Lawrence Berkeley National Laboratory and has been continuously extended over the past several years. The current version supports electric lighting, day-lighting and energy simulations.

The BDA software is designed to facilitate decision making from the early schematic phases of building design to the detailed specification of building components and systems. To do that, the BDA supports the automatic assignment of default values for all descriptive parameters that are required as input for the linked simulation tools and are not usually provided at the early, schematic phases of building design, when spatial arrangement and aesthetic appeal are of primary importance. The default values are based on building type, location and space type and allow BDA users to run performance simulations by specifying only the geometry of spaces and windows. BDA users can of course edit the automatically assign default values as they move from schematic into detailed design.

Technical Implementation

The BDA software operates on three databases, which are accessed by different applications and processes (Figure 1).

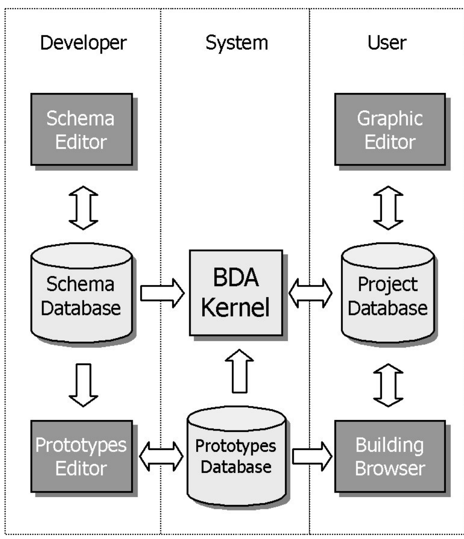

Figure 1. Schematic diagram showing the three main databases used in the BDA software environment, along with the main applications and processes that operate on them.

The *Schema Database* holds all parameter and relation information of all different objects used to describe the building and its context. This database allows expansion of the building model by simply extending the Schema Database through the creation of new building objects, along with new relations and parameter objects for new or existing architecture objects. To support the code compliance capabilities of ATON new objects and new parameters for existing objects were added to the Schema Database, using the *Schema Editor*, a special user interface designed for BDA developers (Papamichael, 1999). The new objects and parameters include layer objects for building components, a thermal bridge object, a ground-conducted boundary segment object, several performance parameters for the *building* object, etc.

The *Prototypes Database* holds alternative values for the various objects used to describe the building and its context. When creating new instances of objects within a building design project, BDA assigns default values depending on building type, site location, and type of space, by selecting them from the Prototypes Database. To accommodate default values for the new objects and parameters related to the European standards, new prototype object instances were added in the Prototypes Database, using the *Prototypes Editor*, another interface designed for BDA developers (Papamichael, 1999).

The *Project Database* holds the actual building representation in the form of interrelated building objects. Data in the Project Database includes the performance parameters that comprise the output of the various simulation tools, i.e., external processes that are linked to the BDA environment. The values of these parameters are continuously updated as the building design evolves. To update the values of performance parameters, the BDA software first determines all required data needed as input by the external processes, then organizes the input data in specific formats, e.g., input files, launches the external processes, waits for them to complete their computations and then retrieves the results, e.g., through specific output files written by the external processes. The updated performance data are then written back into the Project Database.

XML Representation of the Project Database

The BDA software creates the input data for and reads the output data from external processes through special software modules, referred to as “drivers.” This approach requires access to and modification of the BDA source code for the addition of new drivers for new external processes.

To simplify the way that external processes are linked to the BDA and avoid the need for changes to and recompilation of the BDA source code, a new approach to storing the project data is being considered. The new approach is based on XML technology, which allows storing all project data elements in a structured ASCII, i.e., text, file. This file can now be accessed not only by the BDA but by external processes as well. This approach has the potential to allow the development of links to new external processes without need to access and modify the BDA source code.

Introducing XML technology to the BDA opens the door to XML files based on a representation of the Industry Foundation Classes (ifcXML), which represent an open industry standard for object-based representation of building components and systems (www.iai-international.org/iai_international). Unfortunately the current IFC2x specification does not cover all the capabilities of the BDA data model.

User Interface Implementation

The BDA project database is presented to the user trough three different user interface elements (Papamichael, 1997). First there is a CAD-like graphical editor called the Schematic Graphic Editor (SGE), which allows graphical editing of most of the geometric parameters of the building context. However, the most comprehensive representation of the project database is offered by the Building Browser, an interface that contains information about the characteristics of all building components and systems that are relevant to the linked simulation tools and models (Figure 2). While geometric parameters can be drawn and edited directly in the SGE, non-geometric properties have to be altered directly in the Building Browser.

One of the most powerful features of BDA is the capability of holding multiple different solutions using different tools/models/values in one common project.

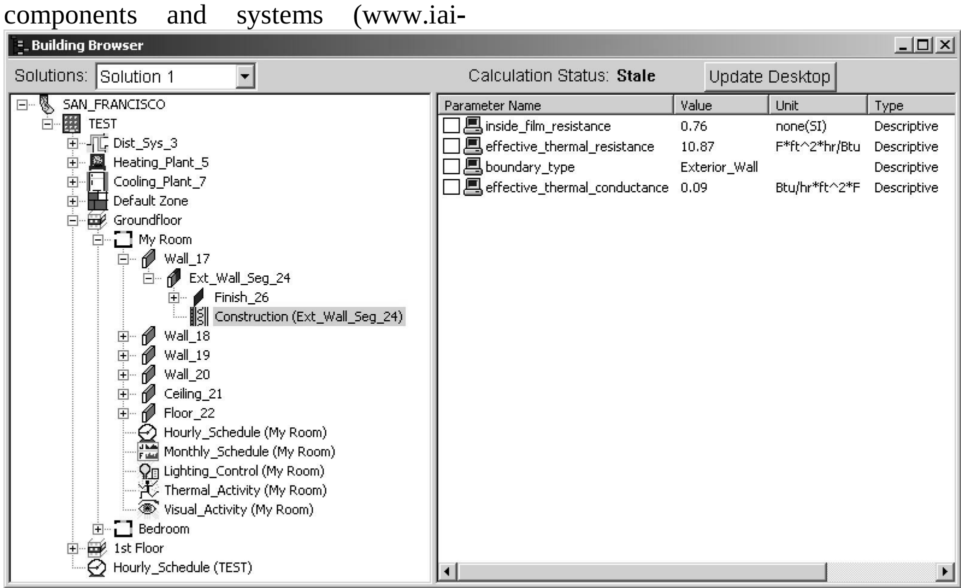

Figure 2. Building Browser displaying the project database

To compare these solutions for decision-making any parameter can be chosen for display in a Decision Desktop, which allows side-by-side comparison of multiple alternative design options with respect to multiple performance criteria. The concurrent use of multiple simulation tools allows for direct comparison of results from different models, e.g., the simplified EN 832 and the more advanced DOE-2 simulation models.

Modifications to the SGE

As all relevant geometric description parameters required for the EN 832 model were already included in the BDA model and SGE capabilities, no modifications had to be made to the Schematic Graphic Editor application. The possibility of adding graphical representation for thermal bridges is being considered for future versions of SGE. Currently, thermal bridges do not have graphical representation and are implemented as building objects that contain the required heat transfer parameters.

Modifications to the Building Browser

The objects and parameters which have been added to the schema database are automatically parsed by the Building Browser according to their defined relations, so there was no immanent need to implement any additional features for manipulating data.

Besides BDA's generic user interface, ATON has a comprehensive variety of its own user interface elements, which can offer additional functionality to the Building Browser for many objects (Figure 3).

In ATON every object has its own user interface, which usually allows manipulation of all dependent parameters in a single view. Through the software concept of ATON it is therefore possible to call each of these interfaces directly by any application. Thus the ATON user interface elements are easily implemented in the BDA environment and called directly from the Building Browser. As the Project Database can now be directly accessed by external processes using the XML project file representation, the Building Browser only needs to hand over the reference key for the desired object to be displayed by ATON and let ATON take control and allow editing in its own user interface elements. When the ATON user interface element is closed, ATON places the edited values back into the Project Database and returns control to the BDA.

This possibility is very helpful when trying to meet specific requirements, like complying with a code. Because now all of the relevant parameters can be modified in a single user interface that monitors all changes immediately, a sufficient solution can be quickly found.

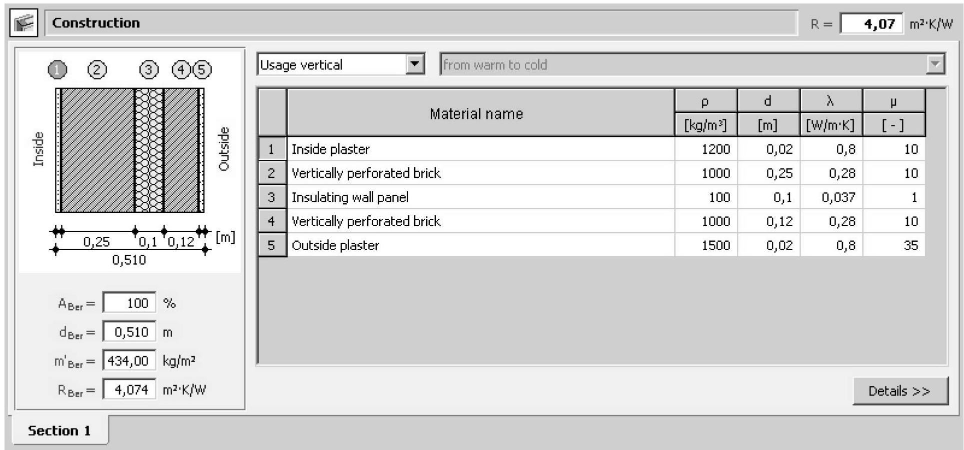

Figure 3. ATON user interface for the construction object

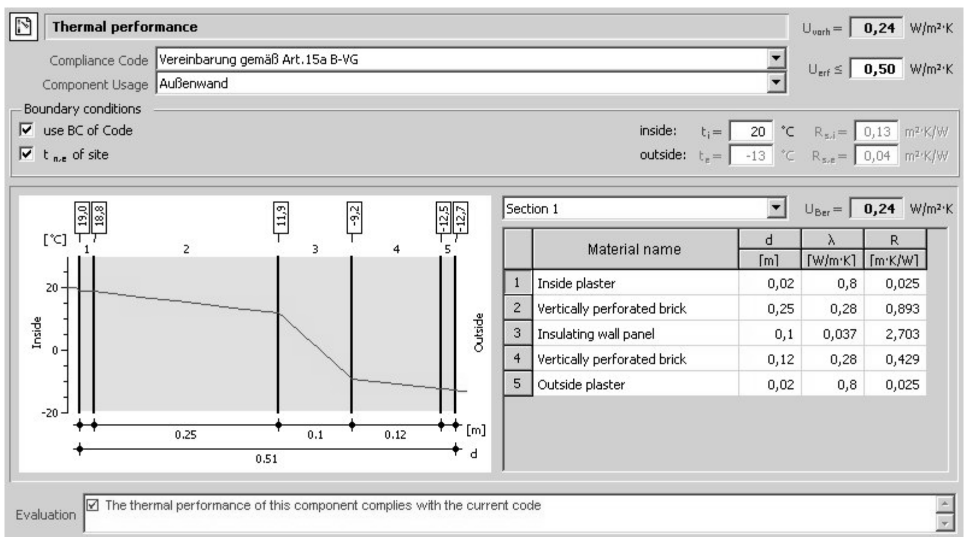

Figure 4. User Interface of the thermal performance code compliance object in ATON

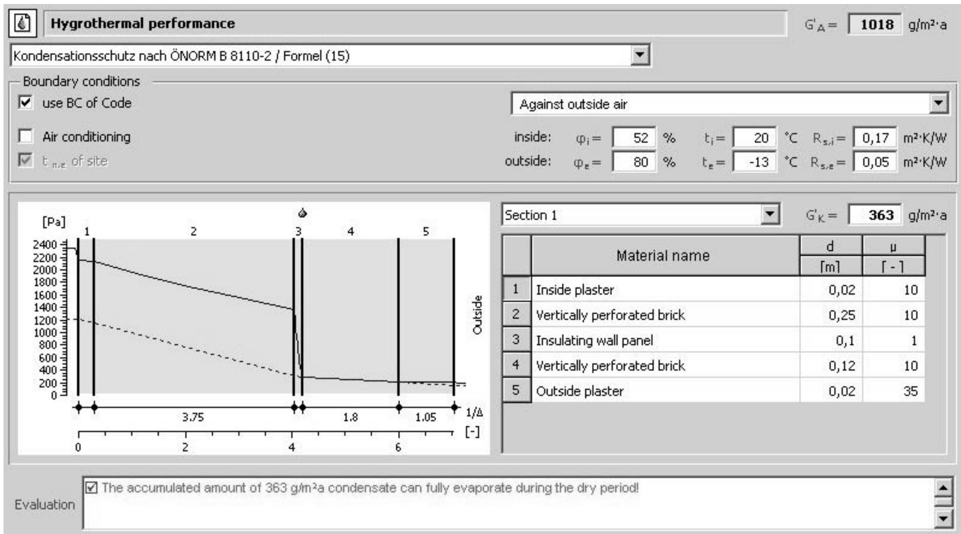

Figure 5. User Interface of the hygrothermal performance code compliance object in ATON

Once the object satisfies the intended performance, the user can close the window and BDA retrieves all updated values from the XML file (Figures 4 and 5).

Modifications to the Decision Desktop

Although all of the parameter/data types needed for code compliance could be mapped to BDA parameter types, the generic graphical representation for some parameters is not adequate for specific code compliance parameters. For example the parameter "complies_with_code" can hold three values: 1 for true, 0 for false and –1 if the compliance is fulfilled under certain restrictions, which are beyond the data description and are referred in the "comment" parameter of code compliance objects. Thus a new parameter type had to be implemented. The values of this type can now be represented in their own graphical representation on the Decision Desktop (Figure 6).

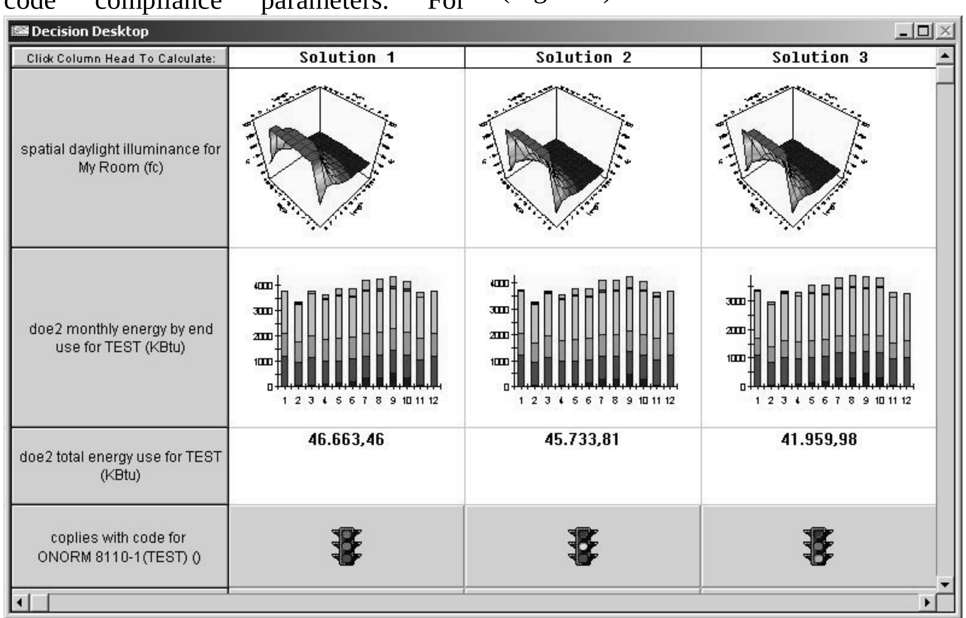

Figure 6. Decision Desktop with "complies_with_code" parameter for the code ONORM 8110-1, which is based on the EN 832 standard calculation model

Furthermore, some of the code-compliance objects offer a "rating" parameter, which allows the comparison to benchmark values. To accommodate such "rating" parameters, another new parameter type was implemented for representation on the decision desktop. This parameter type is characterized through a set of bars, each showing a required value, and the actual value pointing to the corresponding bar in the set (Figure 7).

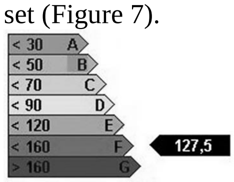

Figure 7. Rating parameter representation for the Decision Desktop

Conclusion and Future Directions

The incorporation of the code-compliance tool ATON into the multi-simulation tool BDA will allow consideration of code-compliance, as well as assessment of performance with respect to electric lighting, daylighting and energy, from the early, schematic phases of building design.

ATON's graphical user interface for individual building objects is most helpful in getting immediate feedback on code-compliance issues and demonstrates how the BDA environment can benefit from customized user interface elements that target specific applications.

Using an XML file to store BDA's building representation is a major step towards allowing incorporation of external processes without the need to make modifications to the core BDA code.

Plans for future work include the incorporation of a U.S. energy code compliance tool, which will make it possible to directly compare the level of requirements in European countries vs. the United States. This will be of interest not only for educational purposes but also for political decisions regarding the development of new criteria for code compliance.

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EN 134651: Ventilation for buildings – Calculation methods for the determination of air flow rates in dwellings

EN ISO 10077-1: Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: Simplified method

EN ISO 10211-2: Thermal bridges in building construction - Calculation of heat flows and surface temperatures - Part 2: Calculation of linear thermal bridges.

EN ISO 13370: Thermal performance of buildings - Heat transfer via the ground - Calculation methods

EN ISO 13786: Thermal performance of building components - Dynamic thermal characteristics - Calculation methods

EN ISO 13788: Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods

EN ISO 13789: Thermal performance of buildings - Transmission heat loss coefficient - Calculation method

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